

## REPORT DOCUMENTATION PAGE

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14. ABSTRACT Suboptimal physical readiness has been demonstrated to result from suboptimal biomechanical, musculoskeletal, and physiological characteristics and is further compounded with poor or inadequate nutrition. The lack of scientifically guided physical training significantly diminishes physical readiness and predisposes the Operator to a greater risk of musculoskeletal injury and impacts the tactical requirements necessary under extreme conditions. Physical conditioning and training remains the cornerstone of the weapons platform as an Operator. Progressive efforts have been made to integrate functional-specific activities into current physical conditioning and training to better meet the demands of combat. Although recent changes in physical conditioning and training have qualitatively provided favorable results, a scientific and systematic examination of training relative to tactical specificity is warranted.						
15. SUBJECT TERMS physical readiness, tactical athlete, culturally-specific						
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OFFICE OF NAVAL RESEARCH FINAL TECHNICAL REPORT  
Naval Special Warfare Injury Prevention and Human Performance Initiative  
PI: Scott M. Lephart, PhD  
ONR Award #N000141010912 (01 JUL 10 – 30 JUN 12)

A. Scientific and Technical Objectives (200 words)

The purpose of phases 1 and 2 of this research project was to scientifically address the current injury prevalence to Naval Special Warfare Group 4/Special Boat Team 22 Operators and identify modifiable contributors to optimal physical readiness. The long-term hypothesis of this research study is that implementation of an empirically-driven injury prevention and human performance program designed to improve biomechanical, musculoskeletal, physiological, and nutritional characteristics will reduce the incidence and severity of injury and surgery, promote Operator longevity, and improve quality of life after service. This research initiative meets the collective desire of Naval Special Warfare to strategically maximize human capital, sharpen battlefield performance, and extend the operational service life of the Operator. A demand-analysis-based, empirically supported, and strategic injury prevention and human performance initiative will be the benchmark for all components of Naval Special Warfare. This research project is a sustained initiative that is culturally specific and dynamically responsive to the unique tactical demands of the Naval Special Warfare Group 4/Special Boat Team 22 Operator.

B. Approach (200 words)

This research is systematically developed based on task and demand analyses of physical training and tactical training, identification of characteristics which contribute to injury, and improvement of suboptimal physical, physiological, and nutritional parameters through specifically designed intervention programs. The overall objective is to reduce musculoskeletal injury and optimize physical readiness and performance.

C. Concise Accomplishments (200 words)

The IRB was approved at the University of Pittsburgh, Naval Medical Center Portsmouth (NMCP), and Navy Bureau of Medicine and Surgery. This process was initiated Aug 06 with final approval 15 Feb 08. Yearly IRB renewals were performed for both the University of Pittsburgh and NMCP. A total of 181 Operators were enrolled in phases 1 and 2 of this research project and underwent a comprehensive human performance assessment for injury prevention and optimal physical readiness to evaluate biomechanical, musculoskeletal, physiological, and nutritional characteristics relative to injury and performance. Specific testing included musculoskeletal strength and flexibility, balance, aerobic capacity and lactate threshold, anaerobic power and capacity, body composition, movement patterns during functional (tactical) tasks, nutritional history, injury history, and tactical performance. For purposes of evaluating the tactical athlete's physical and physiological ability, the human performance data were benchmarked against a group of elite athletes, elite triathletes, or elite tactical athletes (top 10th percentile of Naval Special Warfare Group 4/Special Boat Team 22). A secondary analysis identified subsets of Operators with data below normative threshold values for injury or performance.

D. Expanded Accomplishments (No word limit)

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Qualitative biomechanical analyses were completed on tasks identified by medical and Command personnel as injurious to the upper extremity, lower extremity, and torso. Biomechanical, musculoskeletal, physiological, nutritional, and injury (self-reported and medical chart review) profiles were completed on 181 Operators. Each Operator's data were benchmarked to elite tactical athletes (top 10th percentile of Naval Special Warfare Group 4/Special Boat Team 22), elite athletes, or elite triathletes to identify injurious or suboptimal characteristics. A customized relational database was designed to identify multi-factorial determinants of performance, injuries and tactical readiness.

**Injury:** Data about unintentional musculoskeletal injuries were extracted from the Operators' medical records. The injury frequency among Operators enrolled in this study was 31.9 injuries/100 Operators/year. The common anatomic sub-locations for injuries were the Shoulder (27.3% of the injuries) and Lumbopelvic spine (13.6% of the injuries). In 54.4% of the injuries, Operators were engaged in either physical training or tactical training when the injury occurred. In 13.6% of the injuries, Operators were engaged in recreational activity/ sports when the injury occurred. Common injury types were Strain (31.8% of the injuries) and Pain/spasm/ache (22.7% of the injuries).

**Nutrition:** The majority (~94%) of the tested Operators did not meet the recommended amount of carbohydrate to optimally fuel 90-120 minutes of daily hard physical training (PT) and to restore muscle fuel for consecutive days of PT. Further, 75% of Operators did not consume the recommended amount of carbohydrates for the "average adult male" (low active). Fifty percent of Operators met the estimated protein requirements necessary to increase muscle size and strength. Sixty-nine percent of Operators consumed a diet that had >30% of calories from fat. If foods high in fat replace carbohydrate and protein foods in the diet, such that these two macronutrients fall below recommended amounts, it may impair physical performance. Dietary supplement use was reported in 73% the Operators. The majority of Operators consumed a protein supplement and/or multivitamins and minerals. However, 17% consumed NO-Explode, Jack-3D, or some type of pre-workout supplement. The effectiveness of NO-Explode as an ergogenic aid is not supported by scientific literature nor have the safety issues been adequately addressed in the athletic or military populations. Jack-3D contains Geranium Stem, which behaves like an amphetamine and, when combined with caffeine, is a potent stimulant that may lead to serious injury or death. Geranium Stem is a banned substance on the National Collegiate Athletic Association (NCAA) and World Anti-Doping Agency (WADA) supplement list. Based on self-reported dietary intake, the current data indicate a suboptimal macronutrient distribution to fuel and recover from daily hard PT. To optimize the adaptations from PT, it is recommended to increase daily carbohydrate intake and decrease fat, especially saturated fat. This will provide more energy to the Operator during PT and reduce the reliance on energy drinks and other dietary supplements that may be harmful.

**Task and demand analyses:** Task and demand analyses were conducted at Stennis Space Center, Mississippi and Fort Knox, KY. Biomechanical data revealed that potentially dangerous lifting biomechanics are repetitively being utilized, as well as greater peak accelerations at the tibia and center of mass (COM) during Immediate Action Drills (IADs) as compared to during Live Fire Training (LFT). Biomechanical data also revealed frequent climbing, running, kneeling, and crouching. Nutritional data showed inadequate nutrition and hydration as well as significant

tobacco use, in addition to inappropriate nutrient and hydration timing. Physiological data revealed most tasks to be performed at low intensity, as evidenced by low percentage of maximal oxygen uptake (VO<sub>2</sub>max), heart rate (HR), and Respiratory Exchange Ratio (RER), with the exception of ground IADs, which were performed at a moderate intensity.

**Strength:** Shoulder and scapular strength were all consistent with or higher than the previously reported athlete average as were hip adduction and knee extension. On average, the Operators demonstrated several strength deficits and imbalances in agonist/antagonist ratios when compared to athletes. Strength deficits were present in hip abduction (19%), knee flexion (23% less), torso flexion (23% less), and torso extension (48% less). In addition, the average shoulder protraction/retraction ratio and average knee flexion/extension ratio were 18% and 14% less than the athlete average, respectively. Furthermore, high percentages of Operators exhibited suboptimal strength or agonist/antagonist ratios for the following: shoulder external rotation (22%), shoulder internal/external rotation ratio (60%), shoulder protraction (13%), shoulder retraction (23%), shoulder protraction/retraction ratio (69%), upper trapezius (63%), rhomboids (79%), hip abduction (68%), knee flexion (80%), knee extension (30%), knee flexion/extension ratio (60%), torso flexion (72%), torso extension (100%), and torso extension/flexion ratio (10%). Muscle weakness and abnormal strength imbalances of agonist/antagonist muscle groups may increase the risk of overuse injury due to altered joint mechanics and musculotendinous stress during functional tasks.

**Flexibility:** Flexibility was assessed for the shoulder, knee, hip, torso, and cervical spine. In addition, posture was assessed. Shoulder extension and internal rotation were suboptimal in 100% of the Operators compared to the athlete average. Active knee extension flexibility was also suboptimal in 80% of the Operators compared to the athlete average. Neither normative data nor an athletic model was available for torso flexibility comparison; however, flexion and extension were 20% and 38% below top 10th percentile of Operators, respectively. Compared to the athlete average, lateral cervical flexion was suboptimal in 68% of Operators while 19% and 11% of Operators were suboptimal with cervical flexion and rotation, respectively. Postural assessment identified that 57% of Operators were suboptimal in forward shoulder posture and pectoralis minor length. Limited flexibility and abnormal postures are theorized to be related to injuries such as muscular sprains and strains, subacromial impingement, as well as decreased athletic performance.

**Balance:** Single-leg jump landings in the anterior direction were used to assess dynamic postural stability. The average dynamic postural stability was consistent with athletes; however, 11% and 32% of Operators were suboptimal in the Medial-Lateral Stability Index (MLSI) compared to the elite tactical athletes for the right and left leg, respectively. The Sensory Organization Test was used to isolate the sensory systems used to maintain balance. The Operators' ability to use the somatosensory, visual, and vestibular sensory systems to maintain balance was consistent with the athletes and the elite tactical athletes. The ability to use the vestibular system (Conditions 5 and 6) to maintain balance was suboptimal in 19% and 26% of the Operators compared to the elite tactical athletes during Conditions 5 and 6 of the Sensory Organization Test, respectively. Accurate sensory information is essential to the performance of complex motor patterns, maintenance of joint stability, and preventing injury.



**Biomechanics:** A biomechanical analysis of the scapulae was performed during a humeral elevation/depression task. At 90° and 120° humeral elevation, Operators had approximately 28% less scapular internal rotation compared to the athlete population and 38% greater average scapular internal rotation compared to the top 10th percentile of Operators. In addition, average upward rotation at 90° and 120° were 35% and 21% less than the athlete population and top 10th percentile of Operators, respectively. Abnormal scapular kinematics is theorized to be related to shoulder injuries and pathologies such as subacromial impingement, as well as decreased athletic performance.

**Physiological:** Suboptimal body fat was identified in 80% of the Operators as compared to the athlete population. Anaerobic power and capacity were suboptimal in 88% and 59% of the Operators, respectively, as compared to the athlete population. Aerobic capacity (VO2 max) and lactate threshold were suboptimal in 93% and 59% of the Operators, respectively. Of Operators with data for all physiological tests, 43% of the Operators demonstrated suboptimal body fat, anaerobic power and capacity, aerobic capacity, and lactate threshold.

#### E. Work Plan (500 words)

Research under ONR Award #N000141010912 was designed to scientifically address the current injury prevalence in NSWG4/SBT 22 SWCC Operators and identify modifiable predictors of injury and contributors to optimal physical readiness. A total of 181 Operators were enrolled in phases 1 and 2 of this research project and underwent a comprehensive human performance assessment for injury prevention and optimal physical readiness to evaluate biomechanical, musculoskeletal, physiological, and nutritional characteristics relative to injury and performance. Based on the preliminary analysis of 181 Operators enrolled in Phases 1 and 2 of research to date, the data indicate:

- Identified a distribution of shoulder (35%), knee (30%), back/neck (20%), and ankle (15%) injuries
- Specific anatomical injury distribution included low back pain (17%), meniscal (12%), shoulder impingement (12%), ankle sprains (12%), knee tendonitis/ITBS (11%), and biceps and supraspinatus tendonopathy (11%)
- Command PT and recreational/sports activities accounted for 70% of the injuries with 65% attributed to running and weight lifting
- Higher than desirable body fat
- Insufficient and inappropriate macronutrient distribution diet and high supplement use

Phases 1 and 2 research activities will continue until 30 Sept 2012 and phase 3 will be initiated under the next phase of funding (ONR Award #N000141110929 and future).

- To identify suboptimal physical readiness characteristics in SWCC Operators  
Data collection ongoing- to date 181 Operators have been enrolled.
- To prospectively identify risk factors for unintentional musculoskeletal injuries in the SWCC Operator  
Data collection ongoing.

- To validate NSWG4/SBT22's TAP to modify the suboptimal characteristics identified for the SWCC Operator

Data collection to be initiated 2012- quarter four.

Proposed FY 12 research activities:

Phase 3 Aim 1: To prospectively identify risk factors for unintentional musculoskeletal injuries in the SWCC Operator

Injury surveillance will be performed on SWCC Operators tested under ONR Award # N000141110929 and the current proposal. Injury data will be correlated with biomechanical, musculoskeletal, physiological, and nutritional data to determine risk factors specific to riverine SWCC Operators.

Phase 3 Aim 2: To validate NSW Group 4/Special Boat Team 22's TAP to modify the suboptimal characteristics and injury mitigation identified for the SWCC Operator

Pre and post-testing will be performed on Operators to test the effectiveness of NSW Group 4/Special Boat Team 22's TAP to improve biomechanical, musculoskeletal, physiological, and tactical characteristics (tested under ONR Award # N000141110929) and injury mitigation (current proposal).

Phase 4 Aim 1: To initiate interval testing and longitudinal analysis of Operators assigned to NSW Group 4/Special Boat Team 22

Interval testing will be performed on Operators assigned to NSW Group 4/Special Boat Team 22 and previously tested for musculoskeletal injury, biomechanical, musculoskeletal, physiological, and nutritional characteristics at Crewman Qualification Training or initially upon team assignment. These data will be used as the reference for longitudinal interval testing to assess career decrement and injury prevalence, deployment changes, reference following injury, effectiveness of TAP to improve physical readiness, and tactical readiness.

F. Major Problems/Issues (250 words)

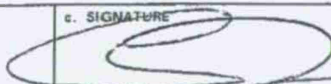
None

G. Technology Transfer

Not applicable.

H. Foreign Collaborations and Supported Foreign Nationals

Not applicable

REPORT OF INVENTIONS AND SUBCONTRACTS (Pursuant to "Patent Rights" Contract Clause) (See Instructions on back)							Form Approved OMB No. 9000-0095 Expires Jan 31, 2008		
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1.a. NAME OF CONTRACTOR/SUBCONTRACTOR University of Pittsburgh		c. CONTRACT NUMBER N000141010912		2.a. NAME OF GOVERNMENT PRIME CONTRACTOR Same		d. CONTRACT NUMBER Same		3. TYPE OF REPORT (X one) a. INTERIM <input checked="" type="checkbox"/> b. FINAL	
b. ADDRESS (Include ZIP Code) University Club, 123 University Place, Pittsburgh, PA 15213		d. AWARD DATE (YYYYMMDD) 20100701		b. ADDRESS (Include ZIP Code) Same		d. AWARD DATE (YYYYMMDD) 20100701		4. REPORTING PERIOD (YYYYMMDD) a. FROM 20100701 b. TO 20120630	
<b>SECTION I - SUBJECT INVENTIONS</b>									
5. "SUBJECT INVENTIONS" REQUIRED TO BE REPORTED BY CONTRACTOR/SUBCONTRACTOR (If "None," so state)									
NAME(S) OF INVENTOR(S) (Last, First, Middle Initial)  a.		TITLE OF INVENTION(S)  b.		DISCLOSURE NUMBER, PATENT APPLICATION SERIAL NUMBER OR PATENT NUMBER  c.		ELECTION TO FILE PATENT APPLICATIONS (X) d. (1) UNITED STATES (2) FOREIGN (a) YES (b) NO (a) YES (b) NO		CONFIRMATORY INSTRUMENT OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER (X) e. (a) YES (b) NO	
None									
f. EMPLOYER OF INVENTOR(S) NOT EMPLOYED BY CONTRACTOR/SUBCONTRACTOR				g. ELECTED FOREIGN COUNTRIES IN WHICH A PATENT APPLICATION WILL BE FILED					
(1) (a) NAME OF INVENTOR (Last, First, Middle Initial)		(2) (a) NAME OF INVENTOR (Last, First, Middle Initial)		(1) TITLE OF INVENTION			(2) FOREIGN COUNTRIES OF PATENT APPLICATION		
(b) NAME OF EMPLOYER		(b) NAME OF EMPLOYER							
(c) ADDRESS OF EMPLOYER (Include ZIP Code)		(c) ADDRESS OF EMPLOYER (Include ZIP Code)							
<b>SECTION II - SUBCONTRACTS (Containing a "Patent Rights" clause)</b>									
6. SUBCONTRACTS AWARDED BY CONTRACTOR/SUBCONTRACTOR (If "None," so state)									
NAME OF SUBCONTRACTOR(S)  a.		ADDRESS (Include ZIP Code)  b.		SUBCONTRACT NUMBER(S)  c.		PAR "PATENT RIGHTS" d. (1) CLAUSE NUMBER (2) DATE (YYYYMM)		DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S)  e.	
								SUBCONTRACT DATES (YYYYMMDD) f. (1) AWARD (2) ESTIMATED COMPLETION	
<b>SECTION III - CERTIFICATION</b>									
7. CERTIFICATION OF REPORT BY CONTRACTOR/SUBCONTRACTOR (Not required if: (X as appropriate))				<input type="checkbox"/> SMALL BUSINESS or <input checked="" type="checkbox"/> NONPROFIT ORGANIZATION					
I certify that the reporting party has procedures for prompt identification and timely disclosure of "Subject Inventions," that such procedures have been followed and that all "Subject Inventions" have been reported.									
a. NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL (Last, First, Middle Initial)			b. TITLE Christine Crawford, Associate Director Office of Research			c. SIGNATURE 		d. DATE SIGNED 6/1/12	